

Topographic Effects on Shelf Waters: A Collaborative Study of Processes Leading to Turbulence and Mixing on the Continental Shelf

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LONG TERM GOAL

Our long-term goal is to develop a deeper understanding of time dependent forcing of stratified flow over topography, such as occurs due to tidal and other coastal currents in the vicinity of banks, shelf-breaks and sills. Of particular interest is the modification of water properties through mixing, the role of topography in producing fluid dynamical drag and the generation, propagation and decay of internal solitary waves.

OBJECTIVES

Our objectives are to measure the response of the stratified coastal water off the coast of Oregon as it is forced over certain topographic features. The research is oriented towards the determination of the internal hydraulic states that evolve in such flows, together with occurrence of shear flow instability, boundary layer separation and other characteristics that combine to determine the response and its influence on the surrounding oceanography. In the case of internal solitary waves, our objectives are to discover the mechanism that gives rise to them and to provide a quantitative fluid dynamical description of their propagation, decay and interaction with topography.

APPROACH

I participated with my co-investigators J Moum (OSU) and L Armi (SIO) on the first of two WECOMA cruises planned within this project. The primary motivation was to study the flow over Stonewall Bank, Oregon although we also found time to investigate internal solitary waves. The locations of ship operations are shown in Figure 1.

My contribution was to use a high resolution back scatter sonar and to combine the resulting images with simultaneous Doppler velocity measurements, together with Moum's microstructure profiles. Stonewall Bank is poorly resolved in available charts, so we spent some effort deriving detailed bathymetry with the vessel following a raster scan (see Figure 2). Having established the bathymetry we conducted a sequence of traverses across the bank in the general direction of the current. At the end of the cruise we spent two days in the northern Oregon shelf waters looking at internal solitary waves. Our approach in this case involved rapid traverses using the back scatter sonar, designed to catch the formation of the waves. Once they were identified, we followed them until they closely approached the shore. As the waves travelled towards the coast we tracked them with a sequence of

short traverses. On many of the traverses, the back scatter sonar and Doppler measurements were supplemented with Moum's microstructure profiles.

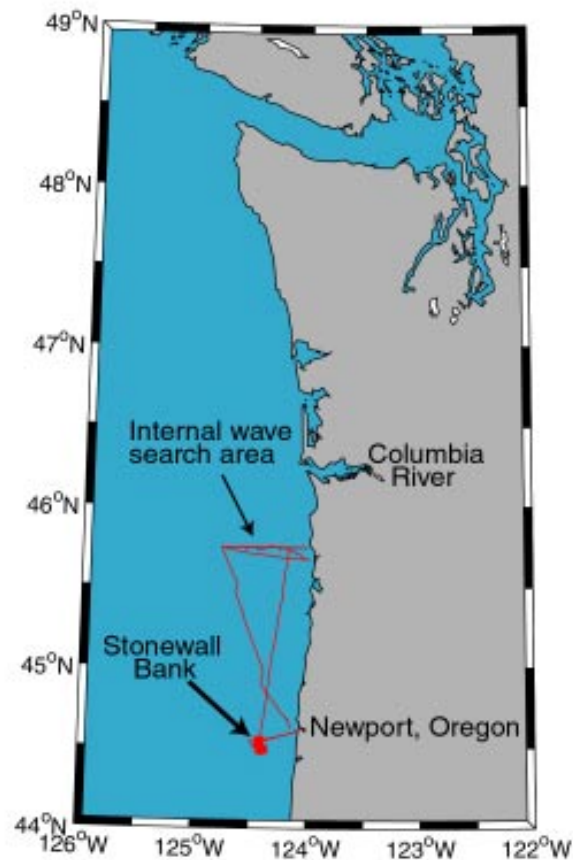


Figure 1: Chart showing area of ship based measurements at Stonewall Bank and further north in our study of internal solitary waves.

WORK COMPLETED

Detailed acoustic and *in situ* measurements were acquired of flow over Stonewall Bank during our cruise in June 2000. The instrumentation worked well and excellent acoustic images were acquired in combination with Moum's microstructure profiles. Extensive ADCP observations were acquired throughout the cruise. Data processing was partly carried out on the cruise and further analysis is presently underway.

RESULTS

For many of the traverses the flow appeared to be controlled at the crest, resulting in a classical internal hydraulic response downstream (cf Farmer & Armi, 1999a). Although detailed analysis of the results has not yet been carried out, preliminary analysis of the data appears to imply that there were situations when this response did not occur and a different behaviour was observed. In these cases the

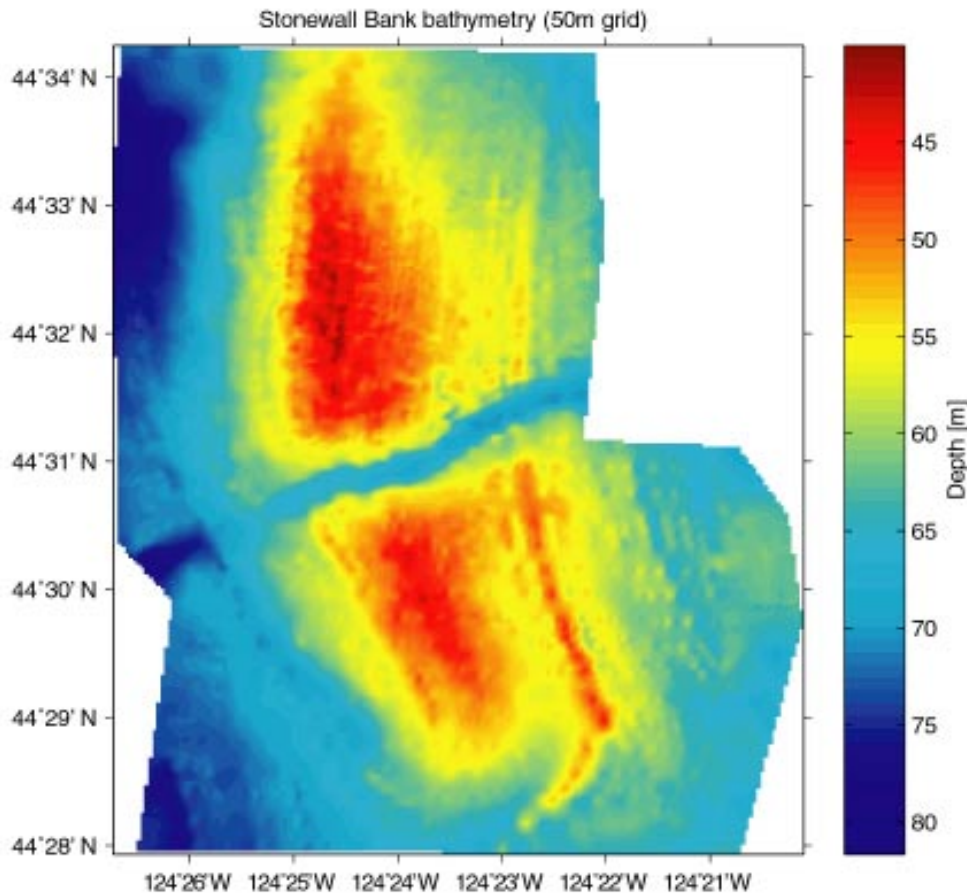


Figure 2: Bathymetric chart of Stonewall Bank. The primary flow was from the north east and most of our measurements were acquired with the ship track aligned with the flow and traversing the norther segment of the bank.

interface did not immediately plunge down the lee face of the bank in the asymmetric response expected for control at the crest, but instead remained approximately horizontal for some distance before jumping down sharply to match the downstream conditions. Figure 3 shows such an example, with the primary flow from right to left and aligned with the vessel's track. This response appears to be indicative of an approach control (Farmer & Denton, 1985) and motivates consideration of the hydraulic state of shelf waters at larger scales when the barotropic forcing is such as to maintain the flow in a supercritical state. With strong enough forcing, the flow can remain supercritical as it moves up and over the bank, reverting to a subcritical state some distance downstream of the crest. This seems to be the case in Figure 3.

Following the study of Stonewall Bank we moved north to the area where internal solitary waves have previously been observed (Figure 1). Repetitively traversing the shelf at speed, we used the back scatter sonar to identify the occurrence of a near surface interfacial disturbance. This subsequently evolved into a train of solitary waves which we then followed for some 30nm as the waves travelled towards the coast. We acquired many rapid traverses, each one followed by a slow traverse in the other direction during which multiple profiles were obtained. GPS positioning was used throughout.

The waves were much larger than those we have previously studied (i.e Farmer & Armi, 1999b). A remarkable feature of the resultant images is the appearance of shear flow instability (Figure 4). The

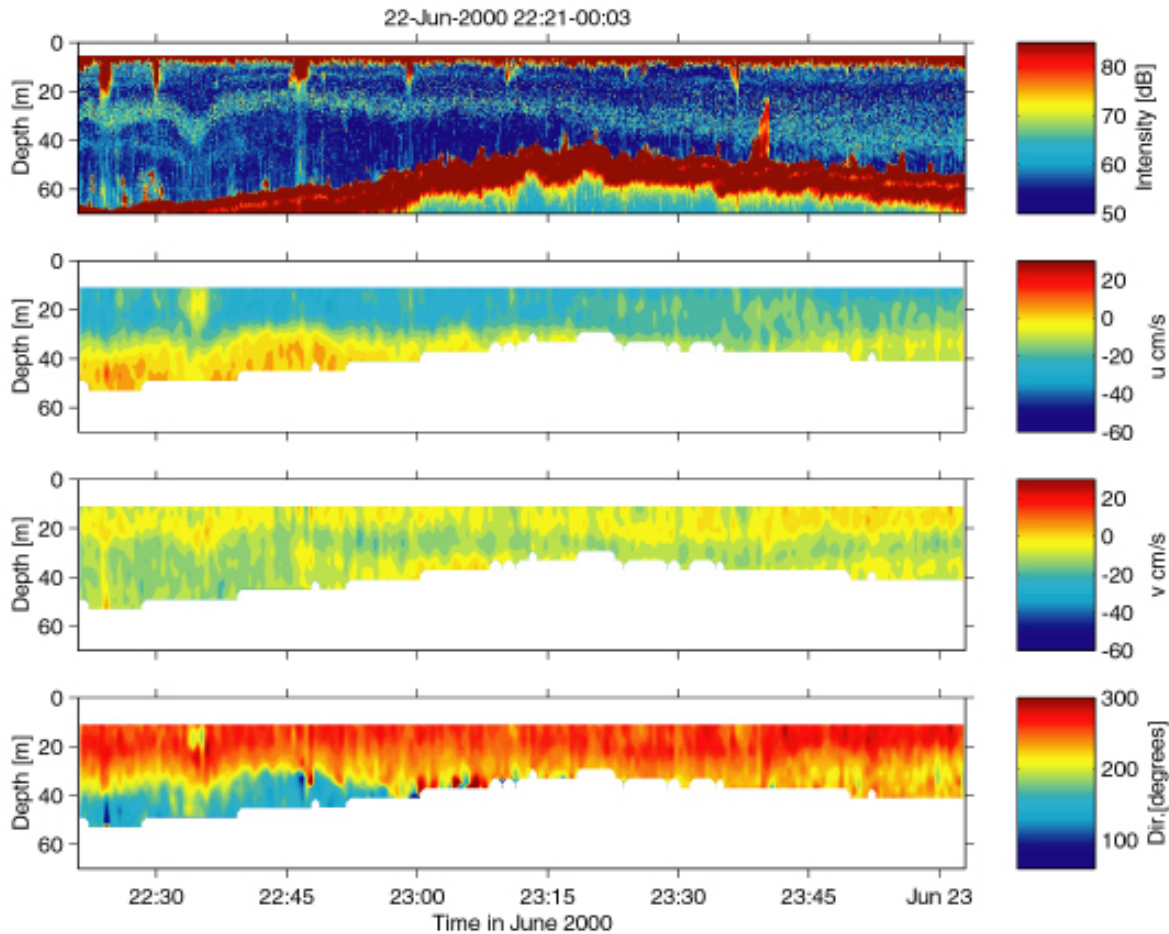


Figure 3: *Top: Echo-sounder image of flow from right to left across Stonewall Bank. The back scatter line in the water column traces the location of the density interface. In contrast to flows controlled at the crest, this does not plunge down the lee face of the sill, but maintains its height for some distance before dropping to match the downstream conditions. We interpret the response as an approach control, which is super critical upstream of the crest. Second and third from top: flow speed measured by ADCP aligned with the ship track and orthogonal to it, respectively. Bottom: Orientation of flow vectors relative to north.*

unstable flow appears first beneath the solitary wave trough and then subsequently grows as the wave passes. This mechanism would seem a likely candidate for dissipation of the waves. A further feature revealed by the back scatter images is the formation of a downwards tongue of surface water within the leading edge of the wave. This is highly visible because of strong scatter in the water, likely caused by suspended bubbles. It is interesting that this high back scatter does not persist through most of the following wave response. The core of the wave appears to be isolated since it does not incorporate the strongly scattering suspensions that show up at the leading edge. Presumably this implies a core of fluid that travels with the wave, as has been postulated in various models of large amplitude solitary waves.

IMPACT/APPLICATION

Flow over banks, which may occupy a small portion of the continental shelf, can exercise a disproportionate influence on coastal circulation. This influence arises from enhanced drag and mixing. As yet, such isolated but important effects are not incorporated as geographically discrete components of larger scale coastal circulation models. Improved representation of these effects requires that we adequately characterise the small scale dynamics, allowing accurate incorporation in

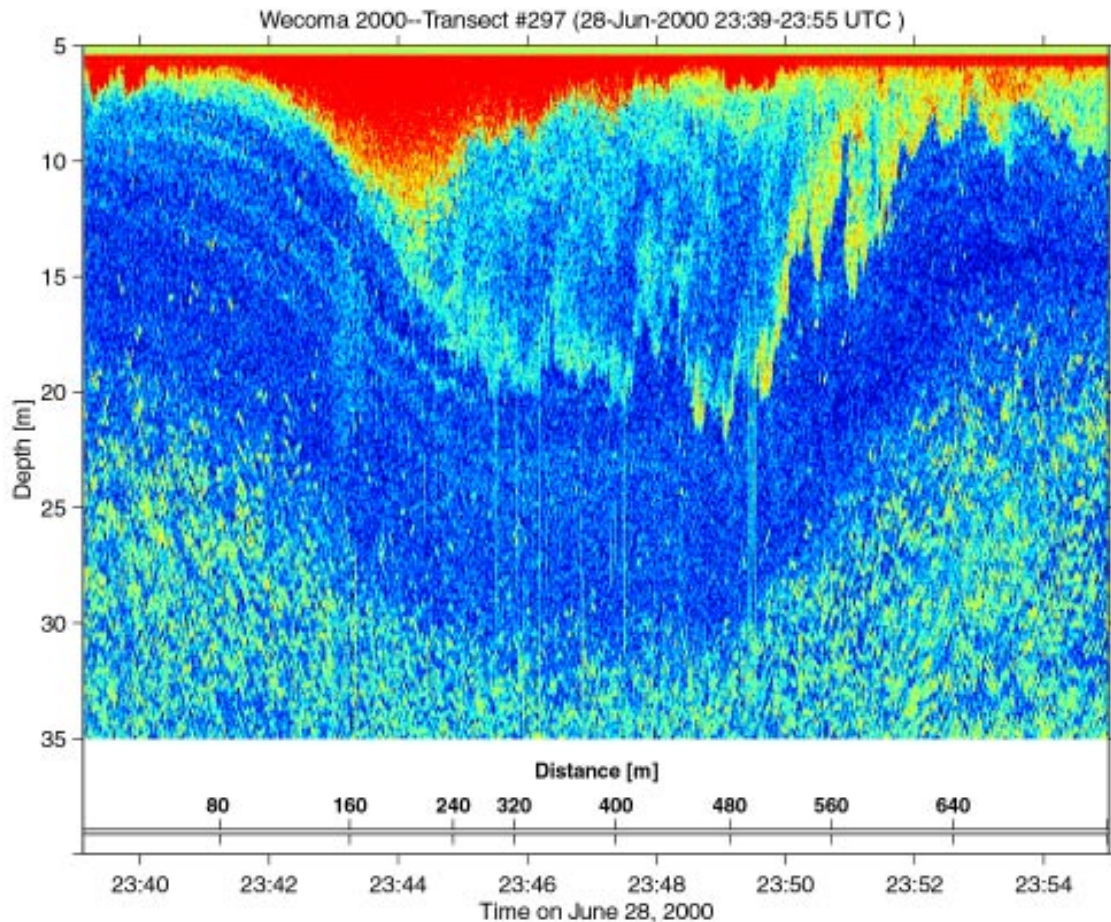


Figure 4: Acoustic image of internal solitary wave. The image reveals clearly the presence of shear instability growing in amplitude as the wave passes. The wave is accompanied by intense mixing. Instability and mixing will contribute to decay of the waves as they traverse the shelf.

the larger scale models. The present work is intended to lead to this result. Similar comments can be made about the internal solitary waves, which are important both because of their contribution to mixing and advection and because of their implications for acoustic propagation and the interpretation of remote sensing images.

RELATED PROJECTS

This project represents a natural evolution from our prior studies in Knight Inlet. The present work represents a close collaboration with Jim Moum (OSU) and Larry Armi (SIO).

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